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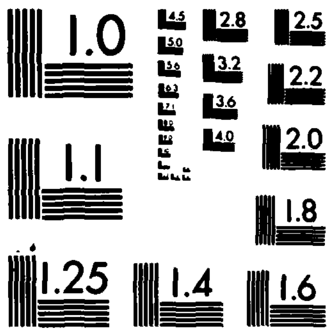

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TECHNICAL REPORT RG-84-8

A PRELIMINARY INVESTIGATION ON THE APPLICATION OF ROBOTICS TO MISSILE FIRE CONTROL

Pat H. McIngvale
Abner D. Sherrill
John W. Herring
Guidance and Control Directorate
US Army Missile Laboratory

NOVEMBER 1983

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35809

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This report explores the possible applications of artificial intelligence and robotics to Army fire control problems. A candidate robotics system is presented and its development is detailed. The system is a ground Remote Target Acquisition/Designation System which would be developed in stages and would make use of technology existing in HELLFIRE, FOG-M, and other related systems. It is intended to evolve from a relatively simple surveillance and designation system to an essentially autonomous fire control system. It has the advantages of removing the soldier to a less hazardous position, allowing the operator(s) to

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oversee the operation of many robotic forward observers, and allowing the acquisition and designation of many robotic forward observers, and allowing the acquisition and designation of targets over a wide area. In the latter evolutionary stages, the system should be equipped with weapons and be autonomous or semi-autonomous.

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I. INTRODUCTION

Robotics technology has been exploited in industry by using robotic devices with varying degrees of sophistication to do boring or tedious jobs (welding an automobile body panel in place), difficult jobs (lifting heavy components into place on an assembly line), dangerous jobs (spraying large amounts of paint or handling radioactive material). Many suggestions have been made concerning the application of this technology to the Army (and other military) missions. These suggestions have ranged from the ultra-fantastic "STAR WARS" machines that will handle all future combat assignments to the very mundane world of automatic weapons loaders, decontamination devices, and so forth.

Just as the industrialist attempts to reduce the labor intensive segments of his operation by utilizing automation, artificial intelligence, or simple robots; the military planner has been considering how the Army of the future can employ robots to reduce the cost and/or improve the effectiveness of the Army. This report documents a short study that was conducted in the Guidance and Control Directorate of the Army Missile Laboratory to consider these applications and structure a technology development program for demonstrating concept feasibility, developing missing technology, and ultimately supporting the development of Army combat robots. In order to somewhat bound the area of consideration (which can be tremendously broad), the missile fire control mission was selected for the proposed robotic application. Even this is a broad area, but it is one in which the general theories and concepts of robotics and/or artificial intelligence can be focused to solve specific problems.

Unfortunately, this report cannot claim to solve any specific problem in missile fire control. What it will do is generally describe a robot and how artificial intelligence may be considered synonymous with robotics in the combat application. Present capabilities will be described in setting the stage for a plan to develop advanced technology. The results of several Army studies on future robotic applications and recommended guidelines on exploiting this technology will be briefly discussed.

Finally, a concept for a Missile Fire Control Robotic Forward Observer will be described along with an evolutionary technology program that begins with current technology/hardware as a remote controlled target acquisition designation system and progresses in steps to demonstrate the full capability of a robot of this type. Although both the Robotic Forward Observer and the technology development program are concepts, an attempt has been made to show the credibility of the concepts.

II. BASIC CONCEPTS OF ROBOTICS AND ARTIFICIAL INTELLIGENCE

The distinction between artificial intelligence, robots, and hard automation is not always clear. The following definitions come from the Army Science Board Ad Hoc Subgroup on Artificial Intelligence and Robotics:[1]

1. Artificial Intelligence: "a programmable machine exhibits artificial intelligence if it can incorporate abstraction and interpretation into information processes and make decisions at a level of sophistication that would be considered intelligent in humans."

2. Robot: "a programmable machine that displays cognitive behavior and performs mechanical and manipulative functions similar to those performed by humans."

3. Robotics: "the study and application of artificial intelligence to manipulative mechanical devices."

The definitions indicate that, while artificial intelligence can exist independently from a robot, a robot requires some degree of artificial intelligence. A model of a robot indicating the function of its artificial intelligence is shown in Figure 1. In this application the robot is simply a control system, either open loop or closed loop depending upon the sensors provided. It consists of the mechanical frame that performs the required physical tasks plus the artificial intelligence residing in an on-board computer. The environmental information from the sensors is fed into the computer where it is interpreted and acted upon to generate commands to the mechanical frame. The robot also informs the human operator of what it is doing if a human operator is in the loop.

The major capabilities of currently available robots are illustrated in Figure 2[2] Capabilities indicated by boxes are those in various stages of early development where major improvements are required before a robot can be produced with more than primitive qualities of dexterity, mobility, sensing, and decision making. For example, the development of jointed arms and opposable fingers with force and tactile feedback could result in a robot with greatly increased dexterity for handling objects of various shapes, sizes, and composition and with the ability to recognize certain objects by touch. Improvements in vision would provide robots with the capability to recognize objects and to pick a specific object from a bin of mixed objects, to recognize military targets or other objects from a video scene, and in the case of mobile robots to pick a path through obstacles from one point to another. The development of a goal directed smart robot with significant decision making abilities is highly dependent on better tactile and visual feedback, both of which will require considerable effort. Another desirable characteristic for a robot would be voice communication capability both to provide information and to receive instructions. Although limited capability is available in this area, major problems caused by different voices, different accents, and especially by the different meanings that words can have in different context must be overcome before significant voice communication with a robot is possible. The other robot capability shown in Figure 2 involves locomotion. This capability is available for rails/tracks and for wheeled/tracked vehicles with a pre-programmed path. Effort is being directed toward the development of legged vehicles under the premise that these would be more efficient in climbing stairs or in navigating a path between two points with obstacles along the way. For either type of mobile robot to successfully move through obstacles to a final goal will require significant developments in vision to locate the obstacles and in artificial intelligence to plan a path to the goal.

The conclusion from these observations is that currently available robots are capable of performing repetitious jobs for which they have been preprogrammed, however, significant improvements in manipulators, sensors, and artificial intelligence are necessary before they have the decision making ability to make their own plans for achieving a specified goal.

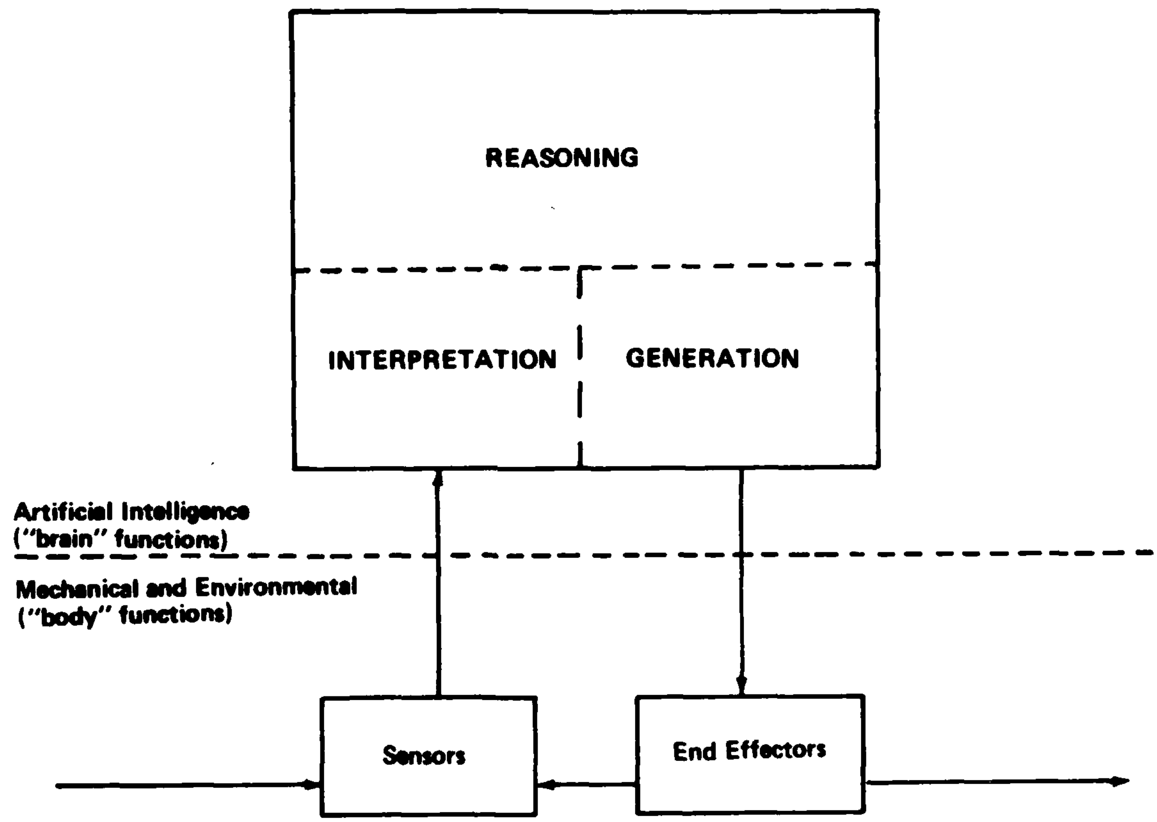
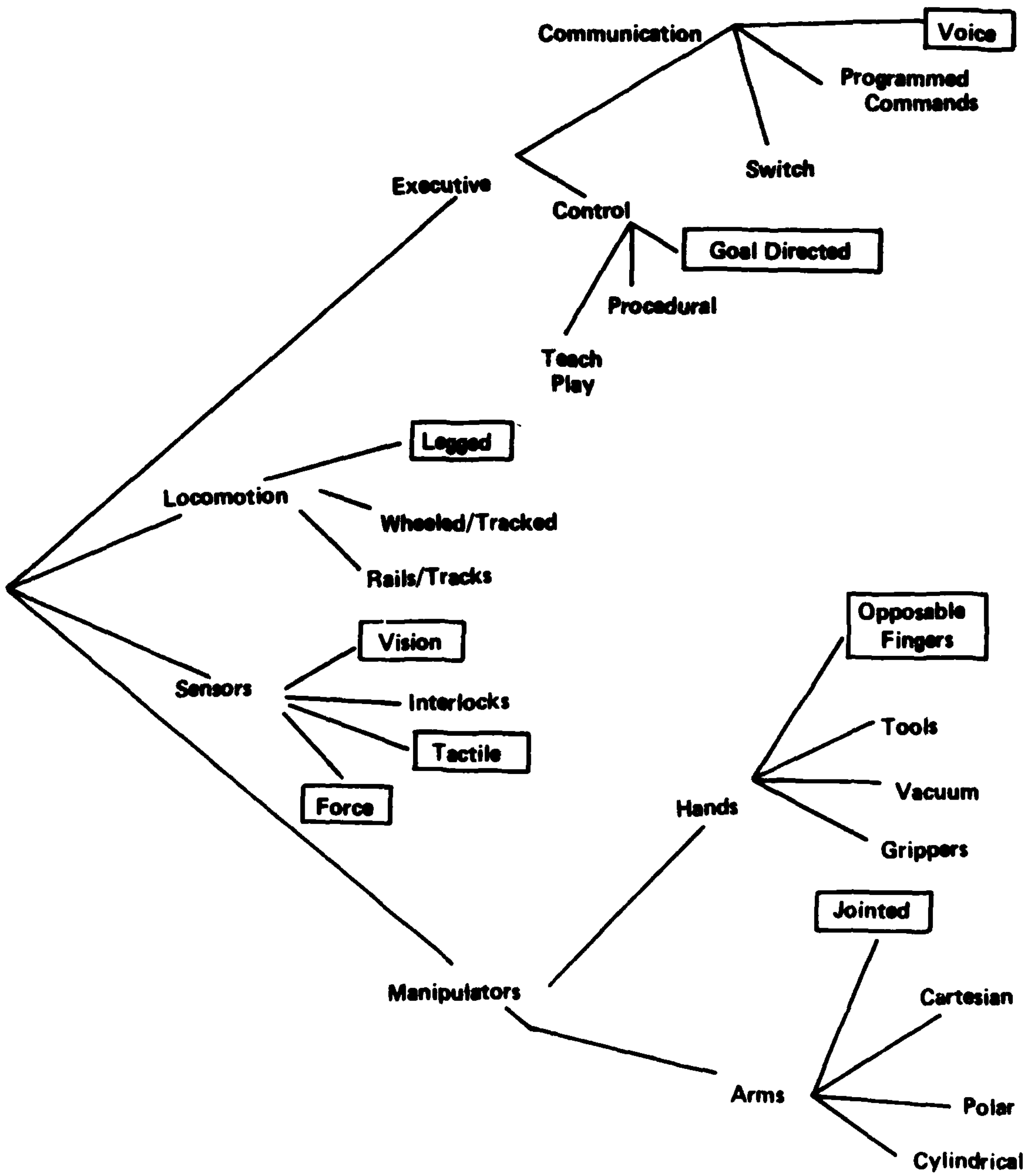


Figure 1. Robot model illustrating "Brain" and "Body" functions.



igure 2. Major robot capabilities.

III. THE APPLICATIONS OF AI/ROBOTICS TO THE ARMY MISSION

The ideas expressed in this section are based primarily on several publications originating within Army research groups directly or through outside contracts [1,3,4,5,6]. Most of the publications reference the Airland Battle 2000 as a basis for the study, with other future concepts also mentioned.

Several general guidelines for Army AI/Robotics applications are set forth in the publications mentioned above. These include the following:

- The development of AI/Robotics systems for Army applications should be an evolutionary process which makes use of presently available weapons and systems. For example, a weapon system might be developed as follows: (1) Remove the man from the immediate vicinity of the weapon by use of a remote control station from which he can remotely observe the battle area, aim, and fire the weapon. (2) Develop the capability for repeated firing of the remotely controlled weapon. (3) Provide the weapon with the ability to recognize the target, aim, and fire. The man would then be removed from the operation except for observation and programming. (4) Make the weapon mobile.

- Systems should result in soldier replacement or force multiplication. It is likely that a threat force would have numerical superiority. Technology provides one means of helping to offset this disadvantage.

- Battlefield systems should result in the movement of soldiers who operate them to a more secure position.

- Systems should be simple to operate and low cost. Operational skills that require excessive amounts of training should not be required.

- Hybrid man-machine systems are most logical, especially in early stages of development. Systems should be designed to provide an effective and efficient man-machine interface.

The desired outcome resulting from the guidelines listed above is to provide effective remotely controlled or robotic weapons and to provide early, accurate, and easily interpreted information for effective fire control under rapidly changing battlefield conditions.

The following Army robotic application research areas were taken from a report[4] by the US Army Engineer Topographic Laboratories. This report summarizes the potential robotic application areas that will be needed by the Army in the future.

Note that items 8 and 9 following are dealt with in somewhat greater detail since they obviously deal more directly with the theme of this report (AI/Robotics Applications to Fire Control).

Ten Necessary Applications Categories:

1. Human/Equipment Interface Aids

2. Planning and Monitoring Aids

3. Expert Advisors

4. Data Assimilation and Access Aids

5. Handling Support Systems

6. Support Systems

7. Situation Assessment Systems

8. System Controllers. These devices would generate instructions to control other systems such as a line-of-sight controller, fire allocation and control systems, helicopter automatic target acquisition and aiming device, target acquisition/allocation system, etc. Varying degrees of human participation in the control decisions would be involved.

9. Weapons. These devices would incorporate varying degrees of target acquisition, identification, and homing capabilities. They would possess the capability to seek out and destroy targets under varying degrees of manual and pre-programmed control by their operator. Examples include a light fighting sentry, infantry robotic grenade, homing tank/killer, etc.

10. Information Collectors

The interesting aspect of the above listing of categories is the fact that many of them, especially those associated with surveillance, fire control, and information systems, have common requirements. For example, improved vision systems to detect and classify targets, reliable narrow beam or fiber optic communication links, and accurate location of target and sensor positions are necessary requirements for many of the proposed applications. The significance of these common requirements is that the basic requirements for several systems can be developed simultaneously. In addition, a single system, through programming or interchanging of modules, can be designed with the capability for performing a variety of tasks. This is a characteristic of AI/robotic systems.

Several advantages in Army applications of AI/Robotics have been mentioned previously. For convenience, these and other advantages are summarized below. The extent to which these advantages apply to a particular application provide a criteria for deciding which applications are most desirable. Advantages of using AI/Robotics are:

- Makes tasks which are otherwise impossible become feasible.
- Multiplies the effectiveness of soldiers.
- Improves decision making under tactical stress conditions by providing more data in a more easily interpreted format.
- Reduces exposure of soldier operating the system.
- Provides systems which can operate in areas where the soldier cannot; e.g., chemical, biological, nuclear (CBN) contaminated areas.
- Provides cost effective systems.

o Resistant to obsolescence.

o Could provide standard systems capable of performing a variety of information gathering and fire control tasks.

IV. A PROPOSED DEVELOPMENT OF A ROBOTIC FORWARD OBSERVER

A. System Description

As discussed earlier, the basic motivation for employing robotic technology in a combat role must be to (a) reduce cost, (b) improve effectiveness, or (c) protect human life; therefore, any proposed "robotic soldier" must offer the potential for providing at least one of these benefits (and preferably more than one). To consider the attributes that a fire control robot must have, it would be well to consider the fire control functions that must be performed by a generic fire control system. The following list of functions would seem to be the minimum required:

o Target Acquisition

o Target Tracking

o Provision of Weapon Guidance Functions (e.g., laser designation, beam projection, lock on for imaging seeker, or precise pointing for unguided weapons.

o Weapon Firing Commands

o Damage Assessment Capability

o Communications with the Weapon Launcher (if not integral)

All these in one form or another must be performed to provide fire control whether the weapon is a gun, an unguided rocket, or a missile. Furthermore, it does not matter where the fire control is performed; whether in a helicopter, a tank, or on the ground with other ground based weapons not part of a larger tactical system (such as a tank).

Robotics would seem to offer possible advantages to any fire control application; however, this study has chosen to avoid those with obvious system implications. For example, a robotic fire control system in a helicopter might be a questionable venture until such time as the entire helicopter was robotically operated. It is likely that the problems of robotically performing fire control in a helicopter are trivial in comparison to the task of implementing a robotically flown helicopter. This is not to imply that artificial intelligence such as automatic target acquisition or target handoff systems do not have an application to these helicopters. It is very likely that such artificial intelligence applications will be realized in the very near future.

Therefore, the study which this report documents considers an "infantry" type robot that can provide missile/rocket fire control without being a part of a major combat vehicle. When considering present fire control tasks in

this category that are being performed by human operators, the forward observer who locates targets and laser designates them for HELLFIRE missiles, COPPERHEAD guided projectiles, or provides data for conventional artillery, comes to mind. The forward observer team must be trained in the use of the laser designator (such as the V/GLLD), the various radios, and digital message devices. Consequently, there is a fairly high expense to train the human soldiers for this mission. In addition, the human fire control operators must be trained to recognize enemy targets and react to them in the most efficient manner in order to be effective. Because of vulnerable position of the forward observer, it is likely his efficiency and effectiveness will deteriorate rapidly during combat. Even counterfire in the general direction of the forward observer can have a detrimental physological effect on him, whether or not the enemy's fire is effective.

Thus, it appears that a robotic forward observer which has no emotions, no nerves, which is never hungry or sleepy and which never suffers from low morale, could be utilized to good advantage. One concept for this robot and its combat application is described in the following pages.

In considering a robotic application, as in any other military R&D undertaking, the most practical approach is to start with those existing subsystems or components that are capable of performing the job and concentrate new design and development on those parts of the system which do not exist. With this philosophy in mind, the Ground/Vehicle Locator Laser Designator (G/VLLD) which is the present laser designator system for the forward observer team is chosen as the heart of the unit along with the FLIR "night sight". The "night sight" is a necessary part of the robot because it provides the electro-optical sensor which is a requirement for electronic image processing or even for operation of the device from a remote location. Since the FLIR is the "visual" sensor of the robot for both day and night operation, it will likely be necessary to upgrade the existing G/VLLD night sight in order to improve the target acquisition range.

The G/VLLD is mounted in a two axis (azimuth and elevation), stabilized gimbal. This gimbal uses gyros for sensing disturbance, digital signal shaping and compensation, and electrical torque motors in elevation and azimuth to provide driving forces. Stabilization will be such as to enable the robot to perform laser designation for both the HELLFIRE missile, the COPPERHEAD guided projectile, and other similar weapons. Although precise stabilization is required, it is to be achieved in a benign environment because the robot would not be moving while designating or tracking targets. The gimbal will interface with the G/VLLD in the same way as the present interface between the G/VLLD and its tripod.

The stabilized gimbal is to be mounted on a simple, built up structure atop the "mobility platform". The mobility platform would contain electrical motors and storage batteries along with the necessary gearing and axles to provide for the robot moving forward or backward. Figure 3 shows a tracked drive on the mobility platform, but wheels could be used as well. If wheels are used, it would likely be necessary to have each wheel driven to make traversing rough terrain more practical. The mobility platform is driven in response to commands from the electronic section.

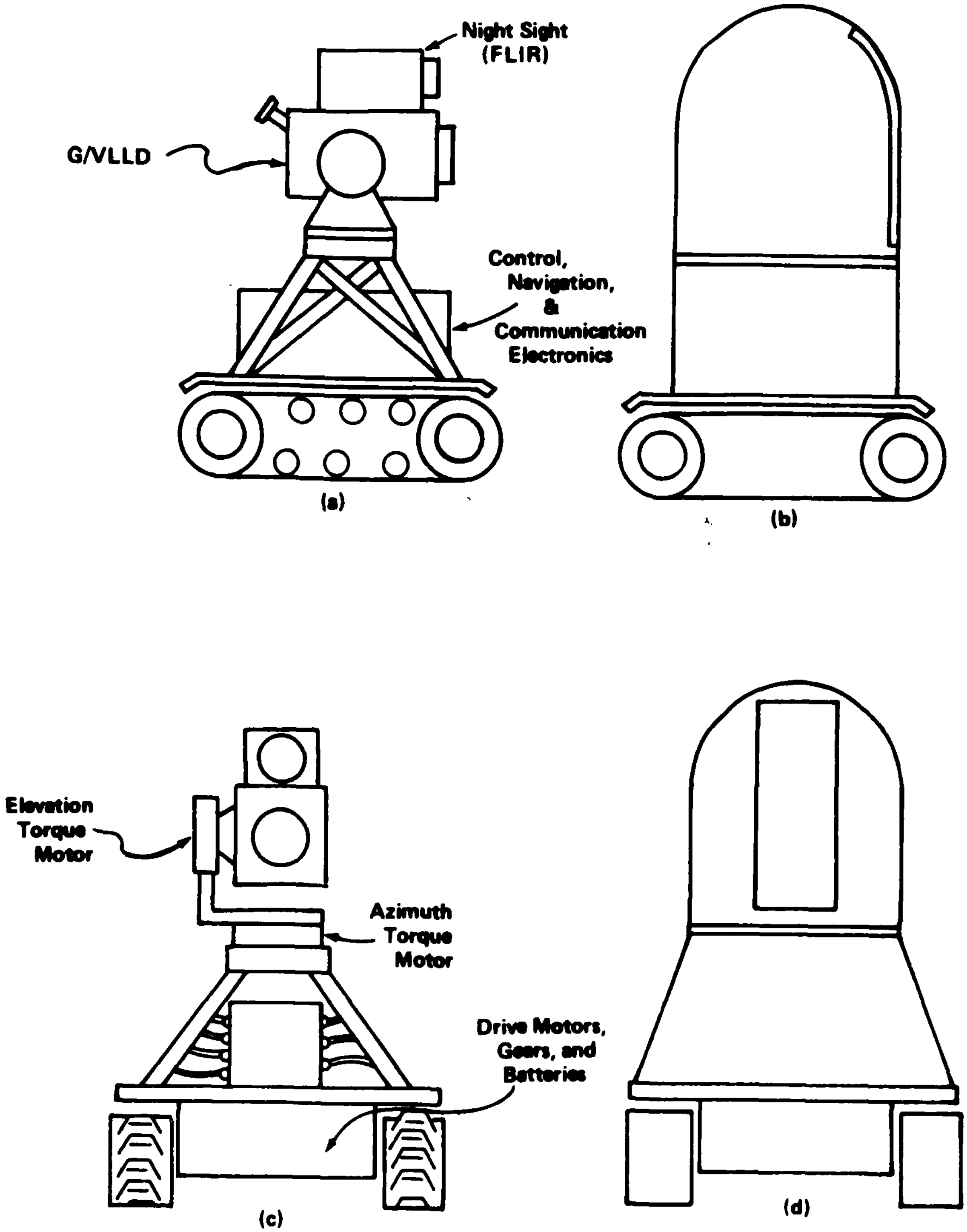


Figure 3. Sketch of a concept for a robtic forward observer for missile fire control. (a) side view, (b) side view with protective cover, (c) front view, (d) front view with protective cover.

The electronic section contains the control/image processing/artificial intelligence that make up the nerve center of the robot. Also contained in this section is the communication electronics necessary to allow the robot to communicate with a remote control center. This communication can be provided by an RF link or through a fiber optic link. Both approaches have advantages and disadvantages and a trade-off study should be made for the possible tactical scenarios to determine which would be most advantageous to use.

It is the artificial intelligence (including image processing) that will make a robot of this type practical. Current technology in automatic target recognition has reached a point of development where it can be successfully applied to a system like this providing that certain constraints are observed. For example, one major problem with current automatic target recognizers is making them robust enough to correctly recognize a very high percentage of targets that come into the field-of-view of their sensor while having a very low "false alarm" rate and operating under all conceivable conditions of background, target aspect angle, target status (moving, parked in defensive position) and so forth. With a robotic application, it is likely this can be simplified considerably. Since the person sending the robot out on a mission will know the general terrain features (from maps or intelligence information), it is likely he can program the robot to search for particular features that are most likely to be encountered in the particular scenario. Research presently underway in the Guidance and Control Directorate of MICOM's Army Missile Laboratory in "Man-in-the-Loop Target Cueing for Missile Fire Control" indicates that such an approach is feasible. Furthermore, the deployment of the robot can be such that if any targets are encountered, they will only be that of a hostile force. This can be done by such things as restraining the directions the robot can search (possible with respect to magnetic north) so that it will not be free to look back at friendly vehicles. There are many other possibilities which should be explored as a separate study.

The electronics section contains the target recognizer along with the rest of the control and artificial intelligence functions. Also contained in this section is the communication electronics necessary to allow the robot to communicate with a remote control center. This communication can be provided by a RF link or through a fiber optic link. A detailed description of the contents of the electronics section and the robotic operation will be given later.

To protect the robot's sensitive electronics and electro-optical systems, it is necessary that a protective cover be provided. Such a cover can be constructed of high impact plastic such as is used for crash helmets and similar devic . This would be tough, fairly lightweight, and of moderate cost. The low(~ of this cover is fixed while the upper part rotates in azimuth to keep t in front of the laser/FLIR apertures. This window is construc of the available materials that is transparent to both near (1 micron (10 micron) infra-red energy. A follow-up servo is provided in the a uth axis to drive the upper turret in response to movement of the laser/FLIR azimuth gimbal.

The contents of the electronic section and the operation of the robot are described in Figure 4. It is envisioned that this robot will be carried to the vicinity of its deployment in another vehicle. It would then be unloaded

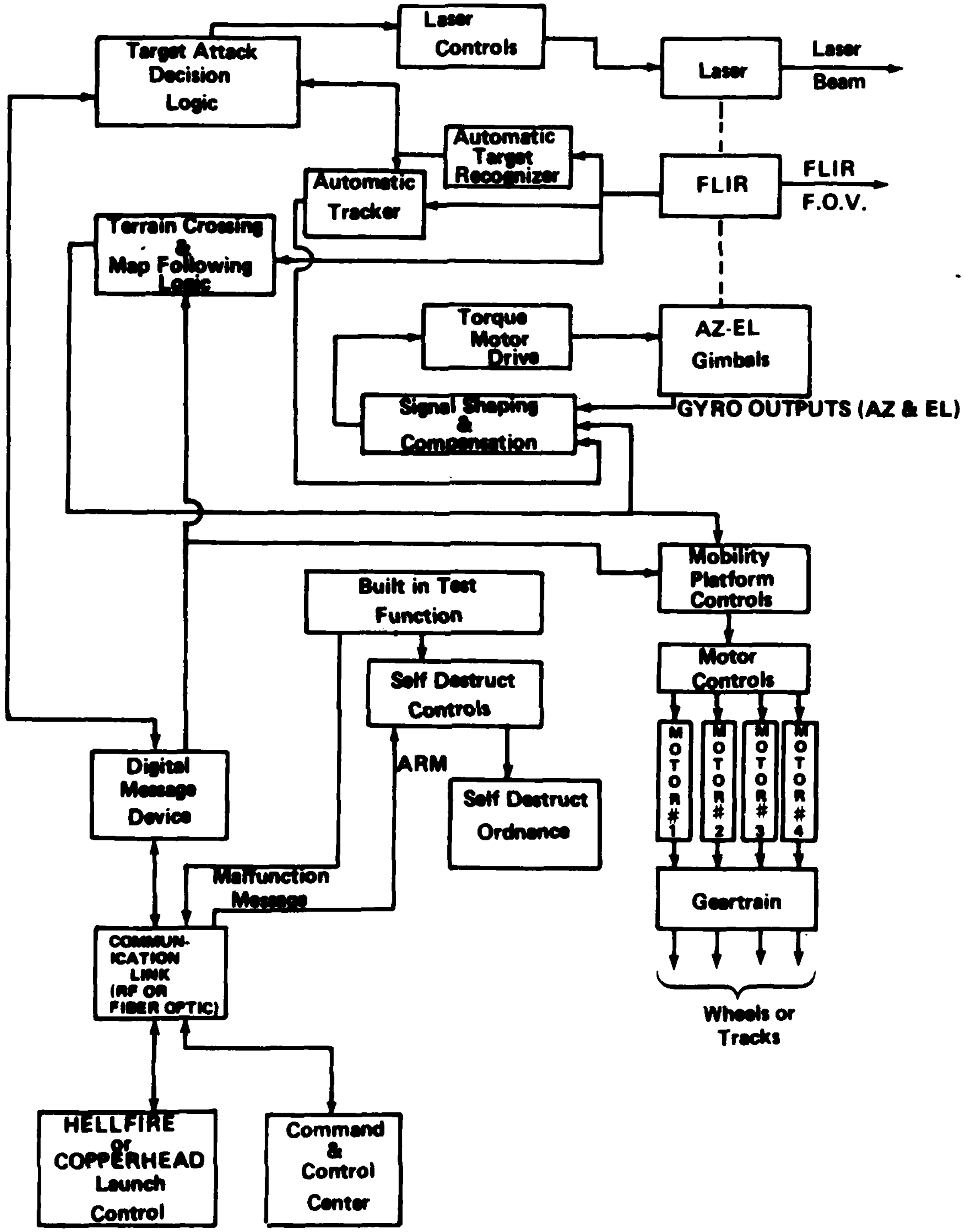


Figure 4. Block diagram of the robotic forward observer essential functions.

and any necessary pre-mission information would be programmed into it from the Command and Control Center (perhaps a part of the vehicle transporting the robot). The Command and Control Center would then instruct the robot to move to its desired location via the communication link. This instruction would include map details to the terrain crossing and a map following logic system as well as commands to activate the mobility system. The robot would move out with the FLIR scanning the terrain ahead of it. The video from the FLIR would be processed in the terrain crossing and map following system to locate and circumnavigate insurmountable barriers, and to do feature matching between the map input information and actual terrain. The output of this system provides steering and speed commands to the mobility platform controls and to the gimbal servo system (to point the FLIR in the desired direction). This system would have a failsafe feature, which will send a video transmission to the Command and Control Center for any situation for which the robot cannot find a solution; so that a human operator can assess the situation and give the robot new or additional instructions. Once the robot reaches the desired position, the terrain crossing and map following system orients the robot (with respect to north or other reference), deactivates the mobility system, and puts the robot in the surveillance and target acquisition mode.

In this mode, the robot requires a minimum level of power since the mobility platform is off as is the laser. The actual operation in this mode will be somewhat terrain dependent. For example, where there is a limited field-of-regard due to terrain features, the FLIR field-of-view may be wide enough to cover the entire area of interest without scanning the gimbals. In more open terrain, it may be necessary to scan horizontally, vertically, or both. This will be a feature that can be pre-programmed or the automatic target recognizer/map following subsystems can be used to make the decision automatically.

As the robot maintains surveillance over its assigned area, the video from the FLIR is constantly being processed in the automatic target recognizer subsystem. This subsystem makes use of various discriminants to separate the features of potential targets from other objects in the scene. These discriminants may be height/width ratio, length, area, and silhouette as well as others. Because the robot will be stationary when searching for targets, it is likely that one of the several means for detecting movement in a series of FLIR images can be used to advantage.

When a target is recognized, the target recognizer activates the automatic tracker which drives the FLIR gimbals such that the target is maintained in the center of the field-of-view (where the laser designator is boresighted). At the same time the target recognizer activates the target attack computer which readies the laser designator for firing, and advises the supporting weapons battery (either HELLFIRE or COPPERHEAD) via the Digital Message Device and the communications link that a missile (projectile) is required for the target. Such information as target range from the robot, type of target, approximate velocity and other data can be transmitted via the Digital Message Device in a very short burst. When the missile (projectile) is launched, a message goes back through the communication link and Digital Message Device to the target attack computer which is the signal to turn on the laser. After the missile/projectile hits the target, the robot's image processing determines whether the target was destroyed and whether or not other targets are present. If the target was destroyed and no other targets are present, the robot goes back to the surveillance mode.

If other targets are available, the autotracker is moved to another target and another fire mission request is sent to the weapons battery. This pattern is repeated until all targets are destroyed or the robot is destroyed by enemy fire, or the robot is overrun by the enemy and automatically self destructs (through a proximity fuse or on command from the Command and Control Center) via its self destruct controls and self destruct ordnance.

The robot also has a means for automatically testing its functions so it can periodically determine its own "state of health". If a malfunction is located when the enemy is not present, the robot will automatically send a malfunction message to the Command and Control Center and technicians can repair the robot. If a malfunction occurs when the enemy is present, the Command and Control Center can arm the self destruct controls so the robot will be destroyed.

There are additional capabilities that can be added to the robot to improve its capabilities. A self defense or attack capability can be added to the robot as indicated in Figure 5. Here, a hypervelocity rocket would be mounted on a second elevation gimbal and boresighted with the laser/FLIR. An elevation servo for the hypervelocity rocket pod would be commanded by the laser/FLIR elevation servo so that the rockets aiming direction always follows that of the FLIR. In this operational mode, the attack computer would solve ballistic equations as required (including inserting a bias into the rocket elevation servo) and fire the rockets automatically.

Another possible addition to improve the overall operation of the robotic forward observer is shown in Figure 6. This modification adds a photovoltaic solar panel and a small positioning servo to the robot to enable solar energy to be used in recharging storage batteries. The servo system (which could be very simple) would simply rotate the base of the solar panel in azimuth to the position where maximum electrical energy is being generated. This modification would not add much to the robot's cost and when the robot was on its station for extended periods of time, some of the energy required for its operation could be generated and restored in the batteries.

A sketch illustrating how these robots might be employed is given in Figure 7. This sketch illustrates that one Command and Control Center (possibly with two human operators) could use several forward observer robots to cover different sectors of a large defensive zone.

If such a robot is built and deployed, what advantages will it offer on the battlefield? Furthermore, does this robotic concept fit the guidelines, mentioned earlier, that have been set out for robotic application? These questions will be considered in the next few paragraphs.

Two obvious advantages offered by such a robotic forward observer are force multiplication or soldier replacement and movement of soldiers to a more secure position. Since one Command and Control Center Team can operate several robots, there is an obvious force multiplication and soldier replacement. With the Command and Control vehicle located remotely behind the robot's positions, the human soldiers are in a more secure position than human forward observers would be. This concept, therefore, offers two advantages that obviously fit the recommended guidelines.

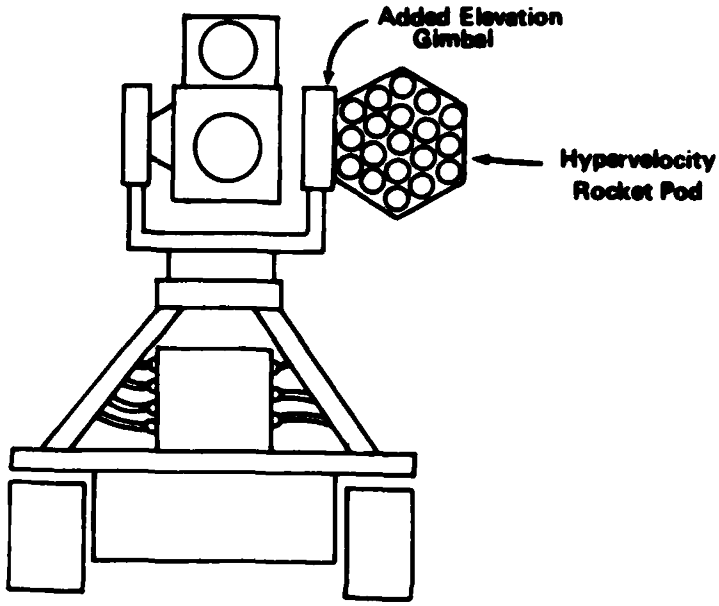


Figure 5. Modification to the robotic forward observer to add weapon firing capability.

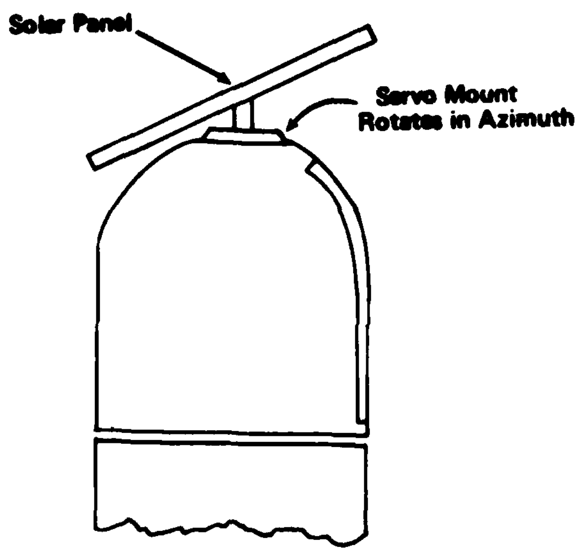


Figure 6. Addition of a photovoltaic panel to use solar energy for battery recharging.

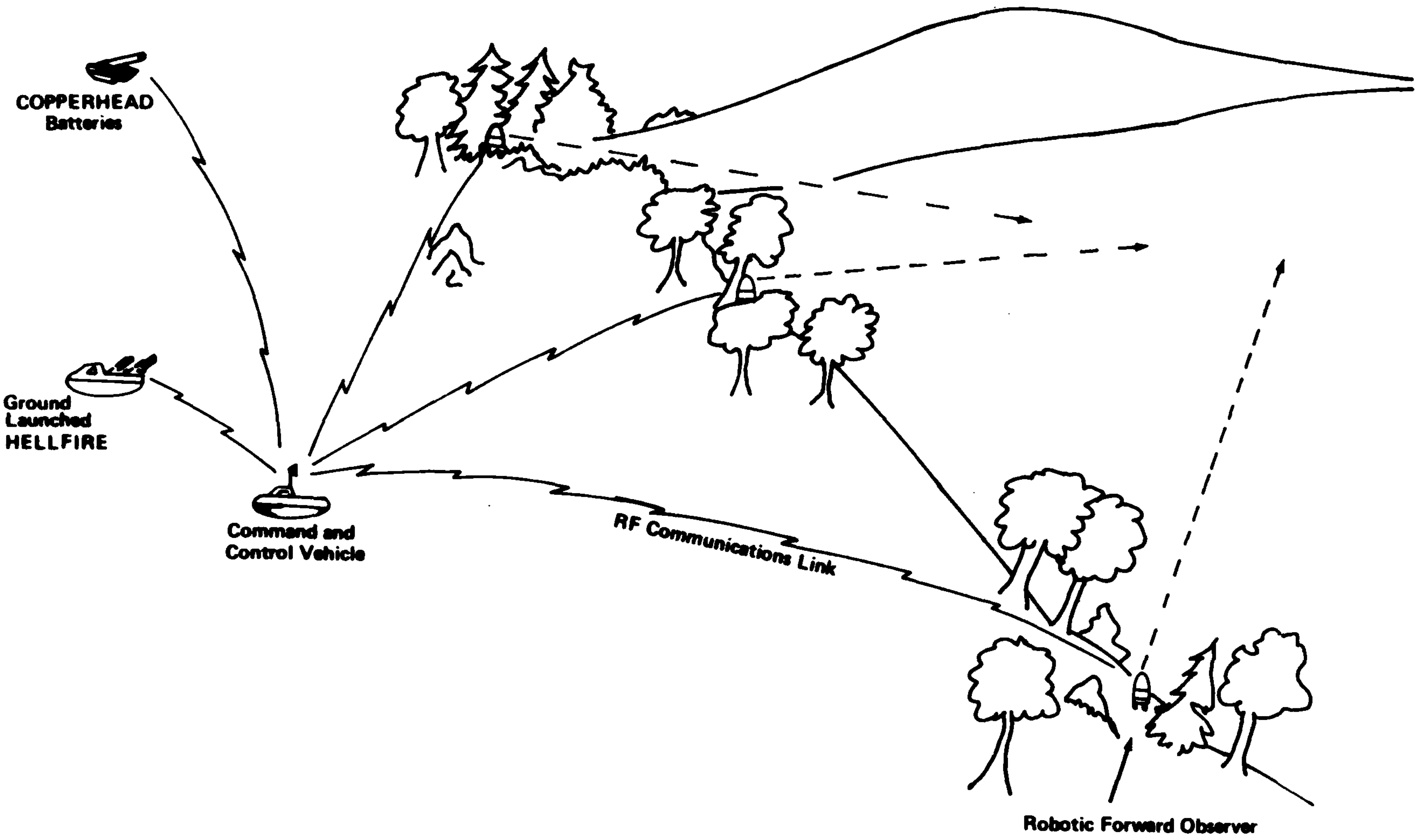


Figure 7. Application of robotic forward observers for laser guided missile fire control.

Another guideline is that the robot should be simple to operate and low cost. Obviously this requires some serious consideration. On the surface, it would seem inconsistent to expect to develop a complex, automatic robotic fire control that is both simple to operate and low in cost; however, since the robot in its final state of development will be fully or almost fully automatic, it will be simple to operate. It will not necessarily be simple to repair, but it should be very simple to operate. Furthermore, although the cost will not be "low" by some standards, the elements are available to make the cost relatively low. For example, the laser designator and FLIR can be units already in production so there should be no significant development costs with them. The artificial intelligence and control may incur respectable development costs, but since the implementation of this will all be done electronically, it seems reasonable to expect that production lot costs should be low. The low cost, high capability home computers of 1983 seem to give evidence that this is a true assumption. It appears, therefore, that a robotic forward observer can be manufactured in quantities for a reasonable cost when compared to the cost of training, equipping, and maintaining a two person forward observer team for the operational life of the robot.

Another guideline is that the robotic systems should be designed to provide an effective and efficient man-machine interface. This concept did not really look into that aspect of the guidelines; however, there is nothing in the concept to preclude such an efficient and effective interface.

Finally, and very important, there is a guideline that recommends that development of robotic systems should be an evolutionary process which makes use of presently available weapons and systems. The robotic system described in this report adheres closely to that guideline. As mentioned already, the laser and night sight (FLIR) are in production, research and development in most of the required artificial intelligence and data processing is ongoing at MICOM and elsewhere while some functions (such as the image autotracker and digital message device) are also in production. The next section of this report will describe a technology development program that will very closely follow the recommendation for evolutionary development.

B. A Plan for the Evolution from Current Technology to the Robotic System

In order to realize a robotic system as described in this report, it is necessary to have a plan by which technology can evolve from that which is presently available to that which is required. The first step of such a plan should be to utilize available technology and demonstrate concept feasibility to whatever extent possible. Each succeeding step should have the goal of adding a discrete capability or technology improvement to the original concept demonstration. The following steps are designed to accomplish this goal:

(1) Demonstrate Remotely Controlled Target Acquisition and Designation

(2) Design, Fabricate, and Demonstrate G/VLLD Stabilized Gimbal Platform

(3) Integrate "Non-mobile" Artificial Intelligence

(4) Demonstrate Basic Human Controlled Mobility

(5) Develop Basic Artificial Intelligence for Mobility

(6) Demonstrate a Prototype Robotic Forward Observer

The following paragraphs will discuss each of these steps with consideration given to (a) technical goals, (b) hardware to be utilized or designed, (c) technology to be developed, and (d) payoff for each step. It must be realized that these steps are oriented toward technology development and infer nothing with regard to proposed schedules or funding.

The first step, that of demonstrating remotely controlled target acquisition and designation, is intended to utilize hardware in existence to demonstrate one or more facets of the feasibility of a robotic fire control system. The Airborne Target Acquisition and Fire Control System (ATAFCS) contains the necessary sensors (TV and FLIR), stabilization, and laser designator to suit it for this purpose. It has been demonstrated that the ATAFCS controls and displays can be remotely located from the turret and electronics via the medium of a copper cable; however, there has been no effort made to provide this linkage via another medium.

Some candidate communication linking mediums are: radio frequency, microwave, laser, and fiber optics. Each of these mediums has characteristics which make it attractive as well as problems which serve to limit its effectiveness and reliability.

Microwave and laser communication links are highly directional in nature which means their signals are hard to intercept and jam. The fact that these signals are directional also leads to several potentially fatal flaws. First, these systems require that the transmitter and receiver be in direct line-of-sight with each other. In a battlefield environment, this severely limits placement of the robotic observer. Another problem inherent with these systems is that they are severely degraded by rain, fog, snow, dust, smoke, etc. These problems eliminate laser and microwave systems from consideration as primary communications links. It is possible, however, they could be considered for emergency backup links.

Radio frequency data links hold promise because they can be made directional and the transmitter and reciever do not have to be in direct line-of-sight with each other. The main problem with RF signals is they can easily be jammed.

Fiber optics is the newest communications medium from a technology standpoint and promises to be the most efficient, reliable, and cost effective. Fiber optics are jam resistant and they can carry many data channels simultaneously. The optical fiber is somewhat fragile, however, and could be severed by various battlefield hazards (tank tracks, random weapons fire, etc.). At present, it seem that fiber optic links should be given primary consideration.

Another plus on the side of fiber optics is that the FOG-M project already employs a fiber optic system which should be readily adaptable for use in a forward robotic observer system.

While the ATAFCS has been used for target acquisition and designation in many helicopter oriented scenarios, there has been little work done in the unique environment of a ground robot; therefore, an experiment and demonstration will be devised to investigate these unique factors. Some of the major areas of uniqueness are:

o A more benign environment since the robot will be at rest when performing its precision tracking and designation functions.

o Targets will present a different appearance when viewed from three feet above ground level as opposed to a hundred feet or more.

o A robot will likely have a clear line-of-sight to a target for a shorter time than a helicopter. The problems caused by this must be investigated.

o Road dust, scintillation, and similar products of the environment may present more difficulty to a ground based robot than to a helicopter. This could degrade not only target recognition and tracking, but could also degrade the laser beam characteristics.

This demonstration will utilize the ATAFCS systems with remotely located displays and controls. Both fiber optic and RF communication links will be fabricated/procured for use in this demonstration. The demonstration will show feasibility of remotely locating, tracking, and designating targets; it will answer questions or allow bounds to be placed on the unique problems associated with a robotic forward observer; and it will allow an evaluation of the two types of communication links under various conditions. As a final part of the demonstration, it is likely that a breadboard automatic target cuer/recognizer can be interfaced with the ATAFCS to begin evaluating the artificial intelligence associated with automatic target acquisition.

The second step in this process will be to design, fabricate, and demonstrate a G/VLLD with a stabilized platform. Provided that the foregoing step yielded encouraging results, the goal in this step is to design the minimum stabilized platform that can carry the G/VLLD and its nightsight and provide the required stabilization and tracking capability. While the first step was essentially a demonstration phase using existing hardware, this phase will require system simulation and analysis, design, fabrication, check-out and, finally, a demonstration under the same conditions as the first. This will be a straight forward engineering task since it is believed that standard stabilization/servo techniques will be fully adequate for this design.

The subsystem demonstration which concludes this step will show the feasibility of performing target acquisition, tracking, and designation from a remote location using the type of laser, FLIR, and stabilized platform that would be practical to put in a battlefield robot of the type being considered. The hardware developed in this step will serve as the first building block in the development of a prototype or breadboard robotic forward observer.

Video target scene data will be collected during these experiments to be used in parallel development efforts on an automatic target recognizer.

The two phases presented thus far described the evaluation of a remote controlled target acquisition/laser designation system and the development of a

G/VLLD, night sight, and stabilized gimbal mount. The third phase will be to integrate "non-mobile" artificial intelligence into the system. The development and application of artificial intelligence to the robotic forward observer is of key importance since without it the robot becomes simply a remote controlled sensor system. Some of this "artificial intelligence" consists of devices widely taken for granted, such as automatic video trackers, while other functions are still in an early state of development. This phase of the development will exploit the AI hardware/software that is available rather than developing new systems insofar as possible. Prototype development of this aspect of the forward observer system will begin by interfacing an "off the shelf" autotracker with the G/VLLD/Gimbal Set/Nightsight. The autotracker will enable the robot to assume some autonomous operation once the remote human operator has located a target and initiated autotrack.

There has been considerable work done in recent years on automatic target cueing/recognition and this is likely to continue. Among the other work being conducted is a man-in-the-loop target cueing development by the Guidance and Control Directorate and the Army Missile Laboratory. This device will be capable of detecting potential targets (in a video scene) and placing a priority on them according to how well they meet predetermined criteria. This breadboard device, or one similar, will be interfaced with the G/VLLD Night Sight. Its purpose will be two-fold: to cue targets to a human operator, or to allow autonomous operation when the human operator is removed from the loop. Experiments will be conducted in both the man-in-the-loop and the autonomous mode.

The third and last device to be considered in this development phase is a "low capability" target attack computer. This computer is to be designed and breadboarded in-house especially for this application using readily available microcomputer technology. This computer will have the capability of taking care of all basic system "housekeeping" and will be the executive controller for the autotracker, cuer, and laser designator. The design and development of this computer is a significant engineering task, but there should be no technology limitations to its accomplishment.

After the above devices have been acquired/developed and integrated, a series of experiments will be conducted to evaluate the robotic system in both the "man-in-the-loop" mode and as an autonomous system. In the "man-in-the-loop" mode, the human operator will acquire targets remotely with the aid of the automatic target cuer. He will initiate the autotracker and laser designator. In the "autonomous" mode, the automatic target cuer will function as an automatic target recognizer. The attack computer will direct the autotracker to lock on the target and will initiate designation as appropriate. This test/demonstration will require ideal conditions in order for the prototype/experimental hardware to operate properly. Nevertheless, if the concept can be demonstrated under more-or-less ideal conditions, then the hardware and software to operate under more realistic conditions can be developed later. This phase concludes with the preparation of requirements for the next generation of target recognizer and attack computer based on the results of the above demonstration.

The next phase of this development will be to investigate basic human controlled mobility. What is needed is a motorized platform capable of transporting a relatively delicate instrument package over rough terrain. The first consideration is the type of power plant to be used. At present, there are only two possibilities - gasoline powered, and electric powered. Each plant has its own pros and cons.

Gasoline driven platforms will have the capability of remaining in the field for extended periods without refueling and would be fairly light and compact. The problems with gasoline drives is that they are noisy and generate a lot of heat; these are factors which make them easily detectable. Also, such drives tend to vibrate; a factor which could damage instrument alignment and repair.

Electric drives have the advantage of being quiet, smooth, efficient, and low heat producing; however, these drives do have some unfortunate disadvantages. Current technology electric drives require large, heavy, short-lived battery packs; therefore, electric drive systems will be short-range and short-lived. It may be possible to tap the advantages of both systems. One might reasonably expect that it should be possible to use a small gasoline engine to charge a battery pack as needed. This approach would allow the unit to stay in the field longer, go farther, and still be relatively quiet. A trade-off analysis will have to be performed to decide which of the three approaches is most reliable and cost effective.

Next, it is necessary to decide whether to use wheels or tracks for locomotion, and what type of drive train best fits the Army's needs. Here again, a trade-off analysis will have to be performed to determine the best route to follow.

Once the above considerations have been decided upon and a mobile platform built, a demonstration of the platform's capabilities will be performed. This demonstration involves mounting a dummy sensor package on the platform along with a simple radio control link. A remote operator then simply demonstrates control of the platform by having it move in any desired direction.

Upon successful completion of the first mobile demonstration, a second demonstration will be conducted with the prototype sensors and computer package onboard. This time, remote operator control will be exercised by viewing the FLIR and communicating via the fiber optic or RF control link.

When the above demonstration has been completed, specifications and requirements for the next generation of mobile platform will be developed.

Phase five begins to apply artificial intelligence to the robotic forward observers mobile capabilities. This is a second AI package that has the responsibility for directing the robot's movements from point to point in response to pre-mission instructions with little or no help from the human operator located at a remote location. The first subset of this capability will be a map-following system. Using currently available scene correlation and pattern recognition techniques, it would seem that a feasible map-follower could be designed. This could also make use of other inputs such as magnetic heading or star tracking. The machine will also be required to locate and identify obstacles and determine the best way around or across them. These capabilities require a fairly high degree of intelligence. For instance, once the machine has identified possible obstacles, it will have to be able to measure the obstacles height, width, and depth as well as the obstacle's relative locations. In addition, it is desired that all of these determinations be made on the move. Also, the machine must be able to gauge inclines and decide if it capable of climbing the hill (based on available power and stabilization criteria).

It is obvious that the artificial intelligence required for this step of the robot's evolution cannot likely be realized with current technology; however, since this is the last step in the proposed development of a prototype robotic forward observer for missile fire control, it seems reasonable that the required technology development can be taking place during the earlier phases of the robotic system development.

At the conclusion of this phase, a demonstration of the complete experimental robotic forward observer will be conducted to show concept feasibility, define operational limits, and suggest required technology improvements required. A total systems requirement for a second generation robot will be generated as part of the program documentation.

V. CONCLUSIONS AND RECOMMENDATIONS

As concepts for future warfare continue to evolve, the Army Commander undoubtedly will decide, as the industrialist has already done, that certain functions can be performed by intelligent mobile machines (robots), rather than soldiers, at a lower cost, either in money, human lives, or both. Furthermore, it will likely be found that certain functions, such as a forward observer for missile fire control, can be more effectively performed by robots since force multiplication can be realized (one human operator supervising the actions of several robots), human soldiers can be moved to more secure locations, and obviously, a machine will continue to function even when threatened with imminent destruction.

Certain guidelines have been proposed by Army research groups concerning the application of robotics to military applications. Along with the principles of force multiplication and the removal of human soldiers to a more secure location, it has been recommended that the development of robotic systems should be an evolutionary process. For example, it was suggested that the human operator first be moved to a safer location and operate his system (weapon, fire control unit, or other) by remote control. Later, intelligence would be added to the target acquisition and engagement functions to enable the remote unit to become self sufficient (so that the human operator would become simply a supervisor or observer). The final phase would be to add mobility.

This report has documented a study effort which proposed a robotic forward observer, capable of automatically acquiring, tracking, laser designating, and calling in laser guided missiles or projectiles on enemy targets. This concept makes use of available hardware (such as the G/VLLD and its nightsight) along with hardware which must still be developed.

A technology development/demonstration program was proposed to carry out the evolutionary development of an experimental robotic forward observer. This process started with demonstrating the remote operation of an Airborne Target Acquisition and Fire Control Systems (ATAFCS) mounted on a ground platform to acquire, track, and designate targets. It proceeded next to the development of a stabilized gimbal and mount for a G/VLLD and nightsight which could also be operated by remote control. Next, basic artificial intelligence was added to allow demonstration of the autonomous target acquisition, tracking, and laser designation functions. Following this, the basic robotic mobility was added with the final step being to add intelligence to the mobility function. The

overall development plan was to utilize current technology to demonstrate concept and define limitations on performance. This will serve as the basis for developing additional technology as required to build an actual battlefield capable robot.

REFERENCES

1. Peden, Irene C., et al, "Ad Hoc Subgroup Report on Artificial Intelligence and Robotics", Army Science Board, September 1982, p3.

2. McIlvaine, H. & G. P. Kearsley, "Human Factors Engineering Considerations for the Planning, Design, and Use of Robots", Human Resources Research Organization, Alexandria, VA, August 1981, p10 (Prepared for US Army Human Engineering Laboratory, Aberdeen Proving Ground, MD).

3. Crumley, D. V., "Concepts for Army Use of Robotic-Artificial Intelligence in the 21st Century", US Army War College Strategic Studies Institute, Carlisle Barracks, PA, June 1982.

4. Brown, D. R., et al, "R & D Plan for Army Applications of AI/Robotics", SRI International, Menlo Park, CA, May 1982 (Prepared for US Army Engineer Topographic Laboratories, Fort Belvoir, VA).

5. Goble, G. W., "Automated WEapons in Conventional and Guerilla Warfare", US Army ARRADCOM, LCWSL, Dover, NJ, February 1981.

6. <u>'83 US Army Mobility Equipment Research and Development Plan</u>, US Army MERADCOM, Fort Belvoir, VA, October 1982, Ch. IX.

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